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OPERATIONAL EVALUATION OF AN INTERIM LOOP DISPLAY SYSTEM

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16. Abstract
An operational evaluation to determine the feasibility of using an interim loop display system to display surface traffic movements in blind spot areas was conducted at the J.F.Kennedy Airport. Specific objectives were to (1) determine the reliability of the system, (2) determine the operational utility of the displayed data, and (3) identify and document relevant technical and operational data to assist in determining future design requirements. The interim loop display system consisted of a logic unit, a display unit and a remote control box. A total of 28 magnetic induction loops was imbedded in the surface of the portion of the taxiway that was not visible from the tower. Loop sensors detected passage of vehicles and the information was displayed in the tower cab. It was concluded that the interim loop display system did not provide a reliable display of aircraft or vehicular movement in the "blind spot" area at the J.F.Kennedy Airport. Many malfunctions of the display system were recorded during the evaluation period. Additionally, many intrusions by ground vehicles at unauthorized points caused erroneous indications on the display. The display system, in the opinion of the controllers, had little or no operational utility The numerous intrusions created a lack of confidence in the system which contributed to this opinion.

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PREFACE

This project was dependent upon support from Technical and Air Traffic Control personnel at the J.F. Kennedy Airport.

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The staff and Air Traffic Control Specialists of the J.F. Kennedy tower.

The staff and specialists of AFS No. 133.

Mr. John Foley, NA-151.

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INTRODUCTION

Purpose

The purpose of this project was to conduct an operational evaluation of the Interim Loop Display System to determine the feasibility of using the system to display the movement of surface traffic in areas not visible to Air Traffic Control (ATC) tower operators. Specific objectives were to (1) determine the capability of the system to reliably display traffic movement in a "blind spot" area, (2) determine the operational utility of the displayed data, and (3) identify and document relevant technical and operational data which will assist engineers in determining design requirements for subsequent prototype model development.

Background

A consequence of proposed airport expansion and construction at the J.F. Kennedy Airport (JFK) to accommodate increased traffic demands and the introduction of wide-bodied aircraft (B747, etc.) was the aggravation of existing tower line-of-sight problems. These areas of non-visibility, which are out of direct coverage of the Airport Surface Detection Equipment (ASDE) or the controller's visual observation, are commonly referred to as blind spot areas.

As a proposed solution to these problems at JFK, the Port of New York Authority (PONYA) initiated development of a Surface Traffic Control System which automatically manages the movement of vehicles and aircraft on the airport taxiways.

As an interim measure, the Systems Research and Development Service (SRDS) developed the Interim Loop Display System. The display system was designed and fabricated at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey. It was designed to provide the ground controller with a visual display of aircraft and vehicular movement in the blind spot area opposite the Pan American terminal complex at JFK.

This operational evaluation of the Interim Loop Display System was conducted during the period July 7, 1971 through September 10, 1971.

Equipment Description

Induction Loops: Aircraft position data were provided by magnetic induction loops. A total of 28 loops was imbedded in the taxiway surface and each was equipped with a detector that sensed the passage of a vehicle over the loop. These loops, 45 feet long and 15 feet wide, were placed so that 15 feet of non-instrumented pavement along both outer edges of the taxiway was available for non-controlled vehicles. The loops were installed approximately 150 feet apart, except at intersections where the distance was approximately 250 feet. The configuration of the loops is shown in Figure 1. Paired loops were installed on all legs of the intersections of taxiways L and I and taxiways Y and I and also at the authorized entry and exit points. Single loops were imbedded in taxiway I between taxiways Y and M approximately 150 feet apart.

Logic Unit: The logic unit (Figure 2) was an enclosed assembly, 18 inches wide, 10 inches high, and 23 inches deep. It was installed in the equipment room below the control tower and was rack mounted. It was designed to receive signal information from the loop detectors, process the data, and transmit it to the display unit for presentation.

Display Unit: The display unit (Figure 3) was an enclosed assembly, 18 1/2 inches long, 6 inches high, and 6 inches deep, and was mounted on the console in the southwest portion of the JFK tower cab. The display panel was a representation of the instrumented taxiway segments with loop locations indicated by slashes perpendicular to the taxiway edge. A series of four miniature lamps protruding from the display face were located within each block and "dummy" block. The lamps were covered with removable colored caps which permitted individual color selection.

Remote Control Box: The remote control box (Figure 4) was an enclosed assembly 2 inches high, 4 inches wide, and 2 1/4 inches deep, mounted immediately adjacent to the display unit. It was equipped with power, dim, test, and reset controls. The power switch regulated the power to the display and the dim control regulated the intensity of the miniature lamps in the display unit. The test switch tested the system logic and display capabilities. Placing the test switch in the up position simulated a large aircrafts' progression through the instrumented area in a left to right direction. Placing the switch in the down position reversed the cycle. The reset button, a momentary switch, when activated emptied the memory in the logic and caused all miniature lamps to be extinguished.

Operational Description

The four miniature lamps protruding from the display face were located in the blocks between the loops and indicated the direction of travel by illuminating three of the four lamps to form an arrow head pointing in the direction of travel.

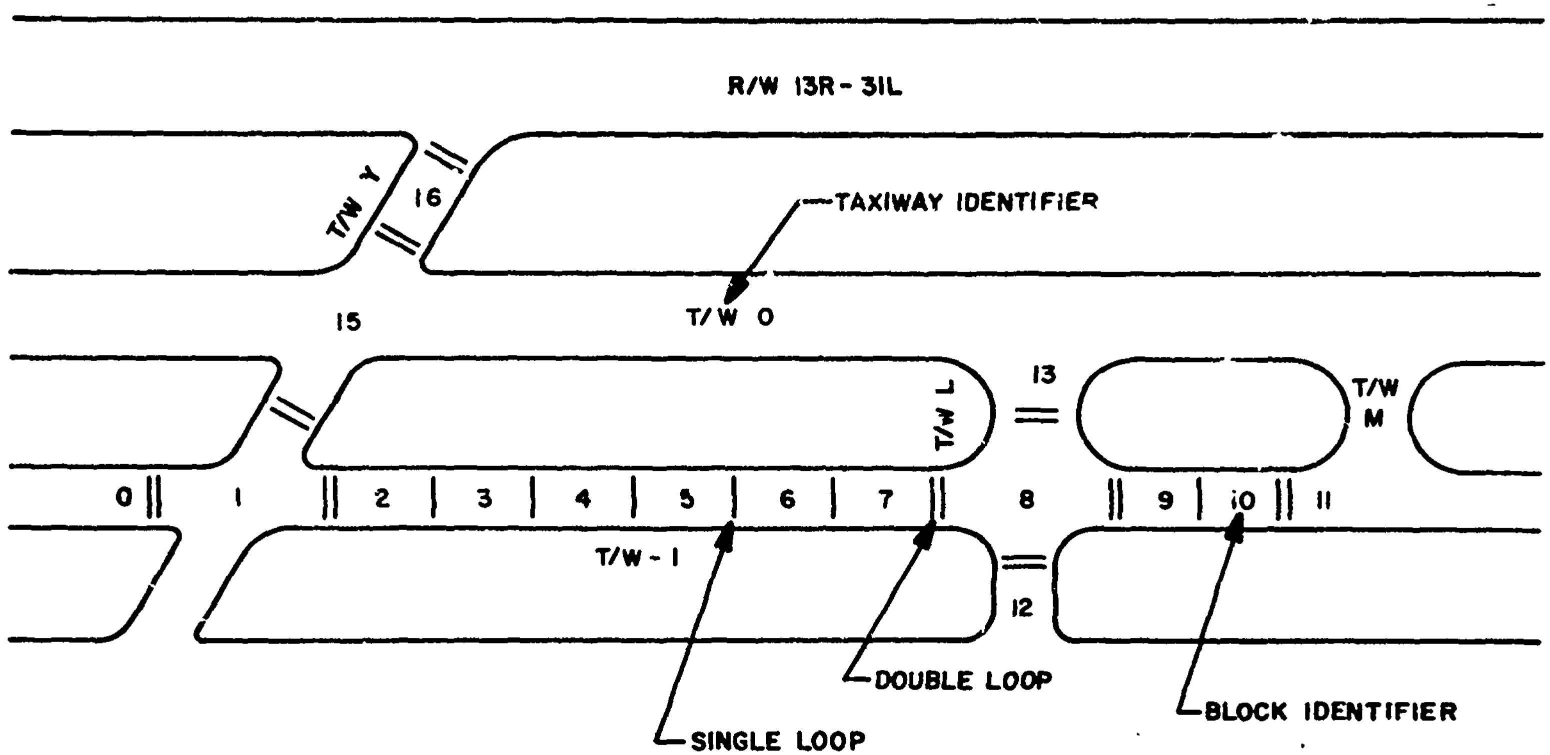

FIG. 1 CONFIGURATION OF INDUCTION LOOPS

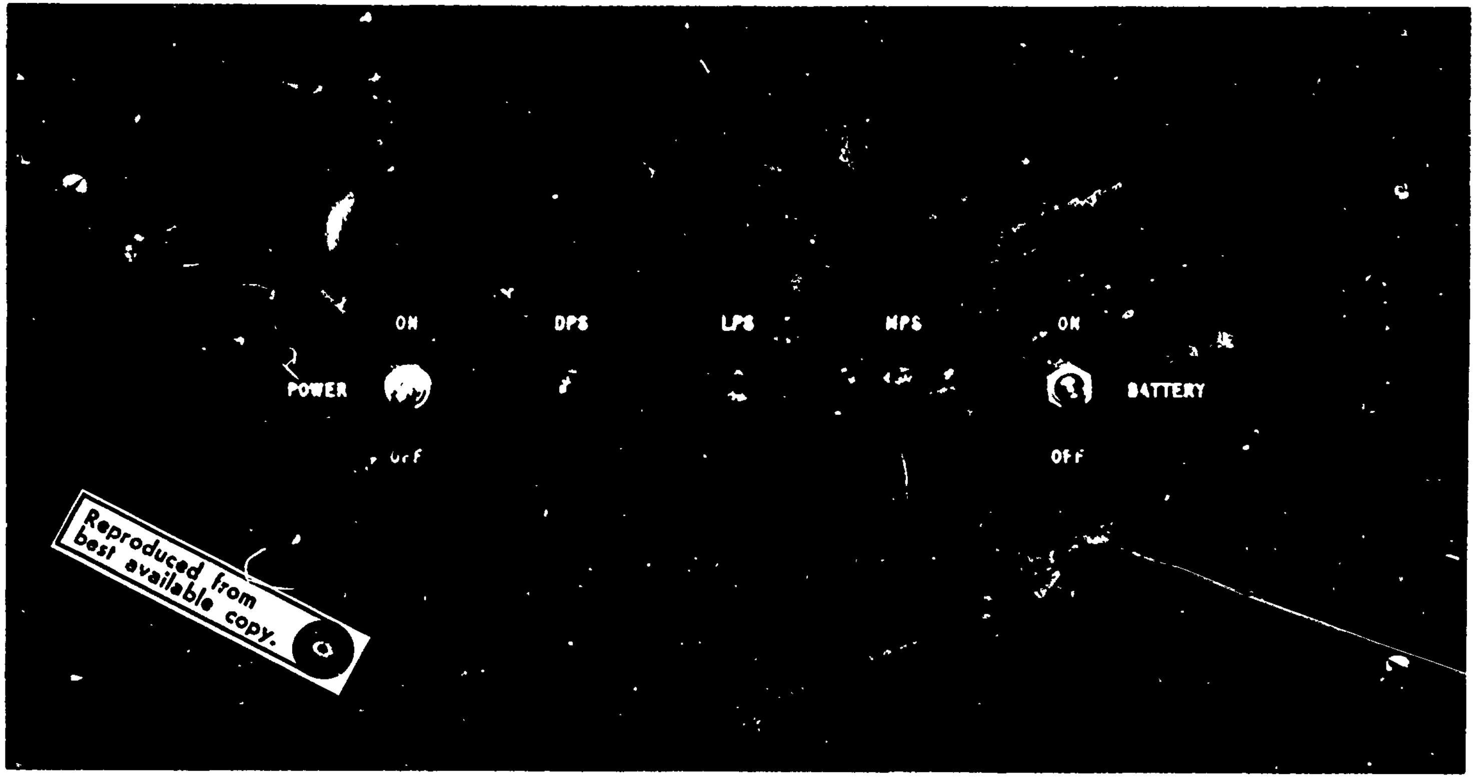

FIG. 2   LOGIC UNIT

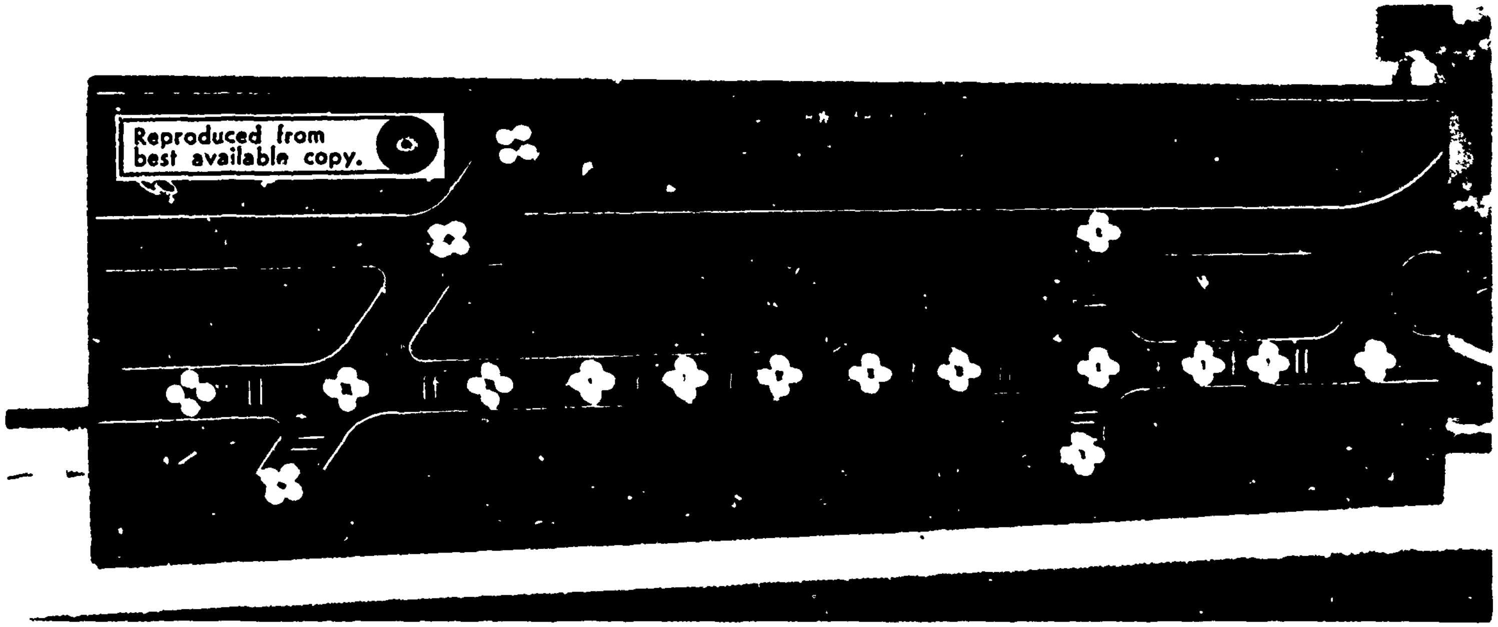

FIG. 3 DISPLAY UNIT

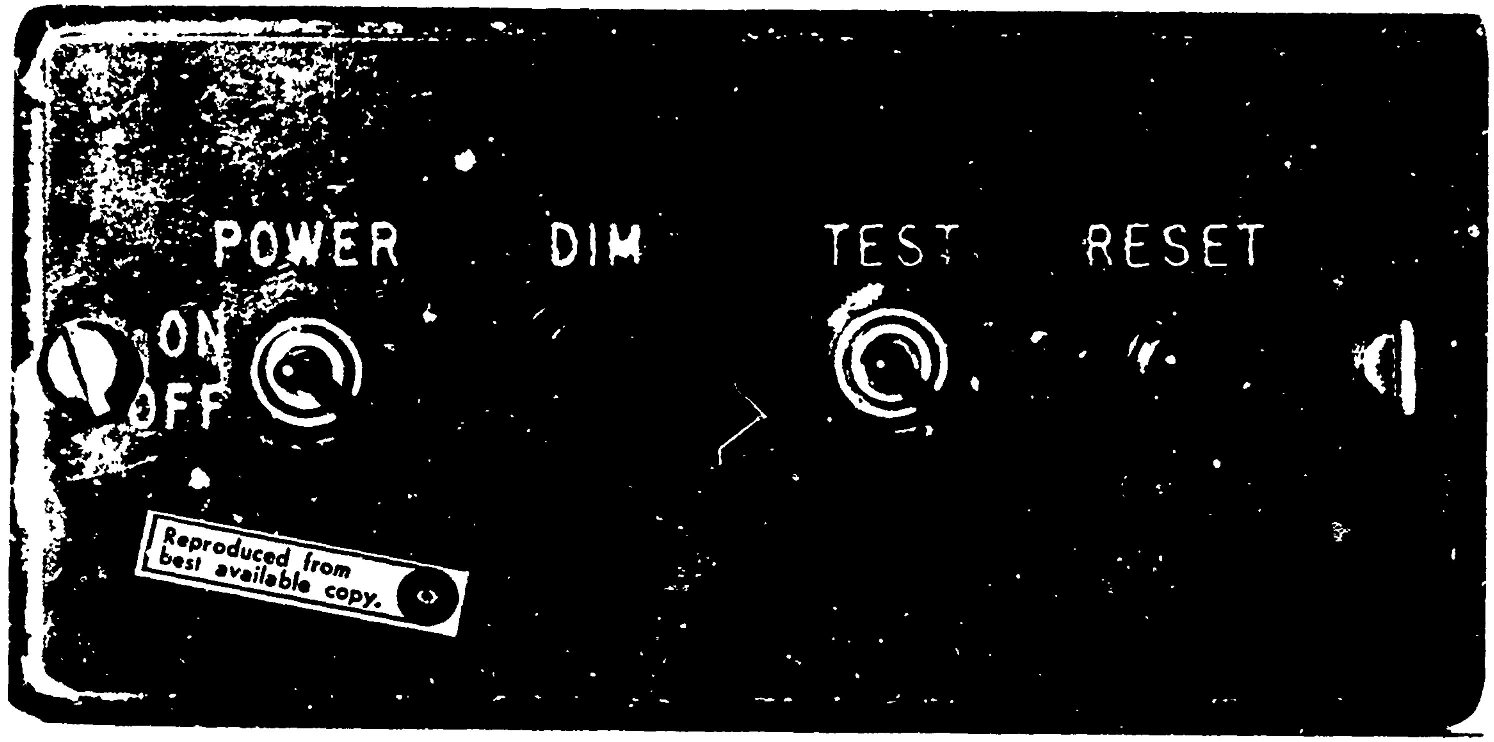

FIG. 4 REMOTE CONTROL BOX

All vehicles and aircraft were required by design concept to enter and leave the system at the authorized entry/exit points, which were the paired loops at the boundary of the instrumented area. Passage over these paired loops established the direction of travel. Aircraft passage over a single loop caused the display blocks on both sides of the loop to indicate the direction of travel. A large aircraft over two successive single loops caused three successive blocks, indicating the direction of travel, to light. Aircraft passage over a paired loop entering an intersection block caused three of the miniature lamps in the intersection block and also in the preceding block to light indicating the direction of travel. When the aircraft cleared the entry loops, the lights in the preceding block extinguished. Crossing the paired loops when leaving the intersection caused both the intersection block and the block being entered to indicate the direction of travel. The system was capable of counting up to three aircraft into a block and subtracting them out, e.g., two aircraft in one block resulted in one lighted display block. As one aircraft left, the lamps in the next successive block illuminated. The lamps in the original block would not extinguish until both aircraft exited that block.

Any vehicle that entered the system at other than the authorized entry points was termed an "intruder." When this unauthorized entry occurred over a single loop, it caused the two adjacent blocks to indicate opposite direction of travel when crossing the first loop. If the vehicle continued on the taxiway, the display lamps would light with progression, but the block indicating the wrong direction of travel would remain lit.

The logic of the system was not designed to accommodate more than one aircraft crossing a loop simultaneously or opposite direction passing. Reversal of direction at any point, except at an intersection block, would also result in malfunction of the display.

The following describes the operation of the display during a typical ground movement through the instrumented taxiway segment, and the reader is referred to Figures 1 and 3 to follow the description: A DC-8 leaves the terminal area on taxiway L. Upon crossing the paired loop entering the system, the upper three miniature lamps in blocks 12 and 8 of the ground controller's display illuminate, forming an arrowhead, pointing toward taxiway O. As it clears the entry paired loop, the lamps in block 12 extinguish. The aircraft then executes a left turn onto taxiway I and infringes on the paired loop between blocks 8 and 7. The lights in block 7 then illuminate in the form of an arrowhead showing right to left movement and the lights in block 8 change, indicating a right to left movement. Since the aircraft is 150.5 feet long, it passes clear of the paired loop between blocks 8 and 7 simultaneously with the infringement on the single loop between blocks 7 and 6, causing block 8 lamps to extinguish and block 6 and 7 lamps to light, indicating right to left movement. As the aircraft progresses through the system, display lamps light in each successive block, indicating right to left movement until the aircraft's passing clear of a loop warrants clearing the display block. When crossing the paired loops between blocks 2 and 1, the lights in block 1 light and when the aircraft is completely in the intersection, the lights in block 2 extinguish. Upon crossing the paired loops between blocks 1 and 0, the directional lights in block 0 illuminate and when the aircraft has passed the last set of double loops, the lights in blocks 1 and 0 extinguish.

DISCUSSION

Test Environment

The operational evaluation was conducted in the control tower cab of the JFK airport. The interim loop display was mounted on the Ground Controller's' console and was located so that visual reference to the display and to the instrumented portion of the taxiway was compatible.

The induction loops were installed in that portion of taxiway I which is shielded from line-of-sight in the tower by buildings in the Pan American terminal complex. Part of this taxiway is constructed of a flexible surface similar to macadam and part with concrete, and it normally serves ground traffic that operates in a clockwise direction.

Aircraft entering the instrumented portion of the taxiway were visible from the tower, with the exception of those leaving the gates of the terminal complex to enter this taxiway. Although taxiway I was not visible from the tower, all aircraft were not completely shielded from view by the buildings. The upper portion of the empennage of most air-carrier aircraft was visible as the aircraft traversed the instrumented area.

Instructions were issued by PONYA officials to ground vehicle operators to avoid the instrumented area since vehicular movement over the loops activated the display in the same manner as aircraft movement. The loop locations were marked with 1-foot wide blue stripes around the perimeter to aid drivers in avoiding passage over the loops. Sufficient room was available for vehicles to pass on the taxiway shoulders to either side.

Evaluation Methods

The interim loop display system and logic was designed and constructed by the Technical Facilities Division of NAFEC. Installation and maintenance of the equipment were accomplished by Eastern Region personnel with the assistance and guidance of the Technical Facilities Division personnel. The induction loops, data remoting equipment, and sensors were provided, installed, and maintained by the PONYA.

Data relative to the utility and suggestions for possible improvement of the interim loop display were accumulated through the use of controller questionnaires. Thirty-six of the controllers were briefed on the operation of the display, and during use of the display were requested to record data that reflected the reliability of the display system.

The evaluation period continued for a period of 60 days, and reliability data were collected for a 2-hour period during each shift. NAFEC project personnel made scheduled visits to the JFK tower to monitor the operation, record observed data, and administer controller questionnaires.

In order to provide additional reliability data, a team of NAFEC controllers spent a week at the JFK tower collecting data during an 8-hour period each day after completion of the scheduled evaluation period.

Results

The reliability data were collected through use of the form shown as Appendix A. A total of 471 observations of movements through the instrumented area was recorded by the JFK tower controllers during the evaluation period. During the week of data collection by NAFEC personnel, an additional 512 observations were recorded. During both periods, the intrusions by vehicular traffic, resulted in numerous false indications by the loop display.

The two most prevalent malfunctions of the display recorded during the evaluation period by the JFK controllers were: (1) block occupancy lights remained lit after aircraft had departed the system (37 instances), and (2) block occupancy lights did not illuminate with passage of aircraft (33 instances). These malfunctions occurred only 4 and 1 times, respectively, during the period when NAFEC controllers were recording observations.

These malfunctions can be attributed, in part, to the logic of the system which will not accommodate aircraft over two different loops of an intersection simultaneously. Example 1: Aircraft A has completely entered an intersection and the memory has recorded one aircraft. Aircraft B is detected at the first loop of a double loop entering the intersection at the same time aircraft A leaves the intersection. Aircraft A is not detected leaving the intersection and the memory attains a count of two aircraft. When aircraft B leaves the intersection, the memory subtracts one aircraft, but the lights remain on since the memory still retains the indication of one aircraft. Example 2: Aircraft A has entered an intersection and the memory has recorded one aircraft. The same aircraft is detected leaving the intersection and a subtraction occurs. As the subtraction is occurring, aircraft B enters the intersection. No addition takes place and when aircraft A clears the double loops and aircraft B is completely in the intersection, the display lights indicating intersection occupancy will go out. However, as aircraft B is detected leaving the intersection, the lights will relight in the intersection and subsequent operation will be normal.

During the initial testing of the system it became apparent that the paired loops on taxiway Y, between runway 13R/31L and taxiway O, were so close together that most air-carrier aircraft were covering both sets of loops simultaneously, resulting in a situation similar to example 2 above. In order to alleviate the problem, the logic was modified so that the following occurred: when an aircraft turned onto taxiway Y from runway 13R/31L and was detected at the first paired loops, the lights in block 16 lit, showing the direction of travel. When the aircraft was detected at the second set of loops (between blocks 16 and 15), the lights in block 15 lit. When the aircraft was no longer detected by the second set of loops, the lights in blocks 16 and 15 extinguished. If the aircraft continued on taxiway Y (did not exit on taxiway O) and was detected by the double loops between blocks 15 and 1, the lights in blocks 15 and 1 lit, showing direction of travel. When the aircraft was completely in the block 1 intersection, the lights in block 15 extinguished. As the aircraft exited the intersection on taxiway I, the lights in block 1 changed showing the new direction of travel and from that point until the aircraft exited the system, a normal operation occurred.

Another frequent, although readily recognizable, occurrence was the activation of a loop outside the normal path of the Boeing 747's, due to the large wing span of these aircraft.

In most instances recorded, the aircraft were traversing taxiway I and while passing block 8 the wing of the aircraft would also pass over the loops that activated the lights in block 12 on the display. Several instances were recorded in which the displays indicated the wrong direction of travel.

A rupture of one of the loops occurred during the test period due to deformation of the taxiway surface. This was reportedly caused by an inadequate bond between the surface of the taxiway and the underlying concrete base. The deformation was present at several of the loop locations, but in only one instance did a rupture of the wire loop occur. Figure 5 illustrates deformation at one of the loop locations. This problem was not encountered at locations where loops were imbedded in concrete.

As noted previously, intrusions by vehicular traffic were numerous, even though definite instructions to remain clear of the instrumented portion of the taxiways were issued by the PONYA. Vehicular traffic in this area was heavy and many vehicles did not comply with instructions for reasons unknown. A vehicle entering or crossing the instrumented taxiway over a single loop would cause the two adjacent blocks to light indicating opposite direction of travel. Passage over an entry loop in an area not visible to the controller would cause display light activation, which was confusing to the controllers. These factors, in addition to malfunctions of the system previously mentioned, contributed to creating the "lack of confidence" expressed by the controllers.

In general, responses of the controllers to questions designed to determine the utility of the system were negative. Although most controllers agreed that the direction of travel could easily be determined, most could not determine the approximate speed of aircraft by progressive illumination of the lights. One stated that in order to determine relative speeds it was necessary to monitor the display diligently.

A large majority of the controllers expressed the opinion that the displayed information was not adequate for making a control decision. Reasons cited were the uncertainty of whether lights were being activated by a ground vehicle or an aircraft and lack of confidence in the integrity of the system. Additionally, if the display was to be used for making control decisions, it would require constant observation, which would be detrimental to control of the majority of the traffic.

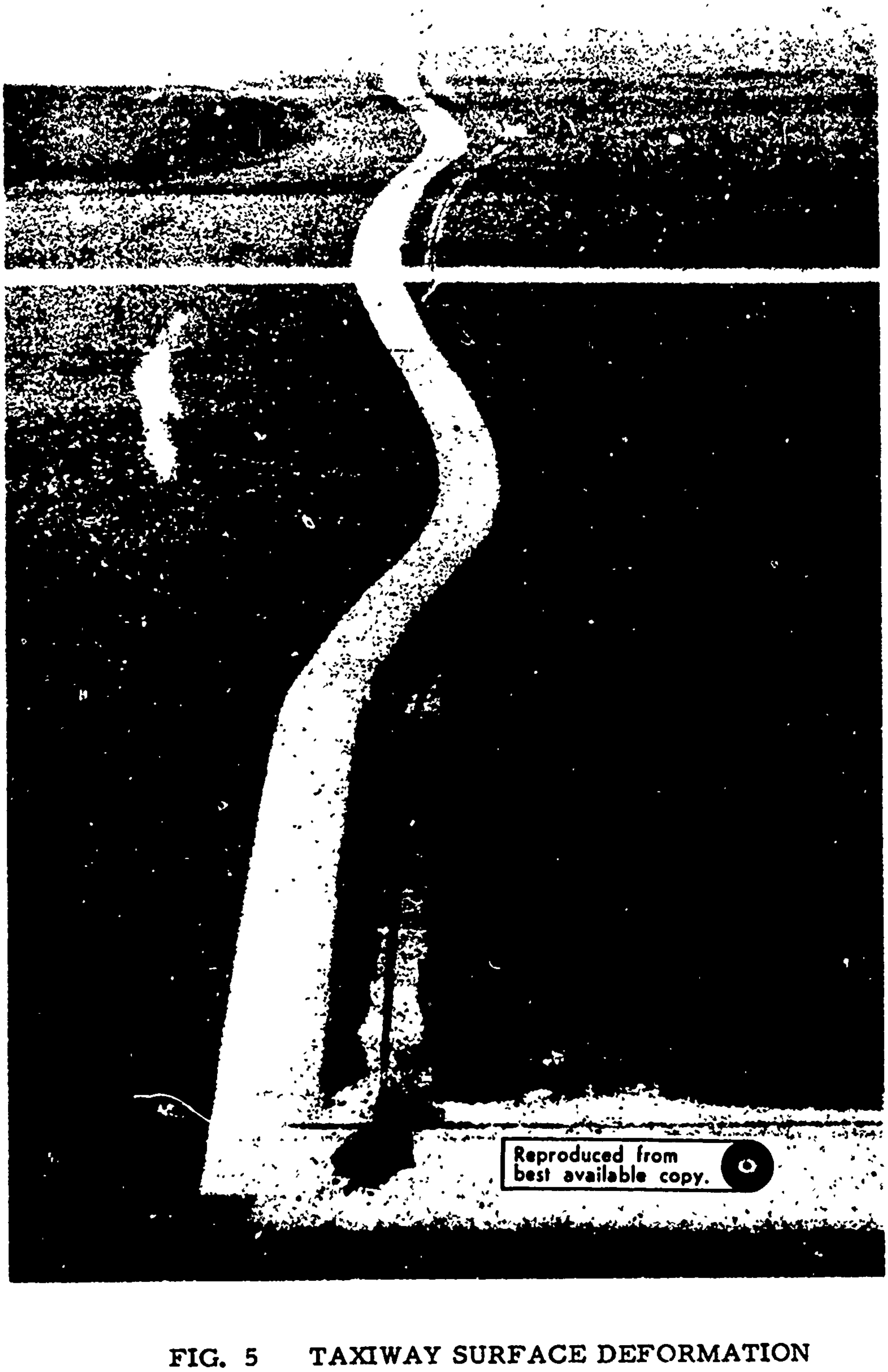

FIG. 5 TAXIWAY SURFACE DEFORMATION

The intelligence gained from the loop display was considered less effective than that of visual observation or than that obtained from the ASDE display. Contributing to this opinion was the general lack of confidence in the display system and the requirement to concentrate attention on the display which represented only a small portion of the area.

Only two instances of unusual weather conditions affecting the display were recorded. In one instance, it was reported that heavy rain caused display lights to flash as if the test switch was activated; and in the second, heavy rain caused the display lights to remain on. These two reports are not considered conclusive since other instances of heavy rain were observed with no apparent effect upon the operation of the system. Other seasonal weather phenomena, such as ice or snow on the taxiways, of course, was not present since the evaluation was conducted during summer months.

The majority of the controllers expressed the opinion that it was not difficult to retain identity of an aircraft on the display unit by correlating the aircraft position with the observed block illumination. However, one expressed doubt if this would apply if a larger area, such as the entire airport, was encompassed.

The interim loop display, in the opinion of the controllers, had little usefulness. However, it must be noted that their opinion was influenced by the malfunctions of the display and by the number of intrusions of the system. Comments on the lack of usefulness included the statement that the display did not provide information to aid in identifying the aircraft, and that the display simply showed that something--an aircraft, a car, or a truck--was in the area. Another statement indicated that the intelligence gained from the display did not warrant diversion of attention from the main flow of traffic.

The physical features of the display were generally considered satisfactory. Green was the favored color for the block occupancy lights by the majority of the controllers. Some bulb failure was noted, but not to a great degree and a few of the controllers believed that the display unit should be smaller.

CONCLUSIONS

Based on the operational results of the project it is concluded that:

1. Use of the interim loop display system is not feasible because it does not provide a reliable display of traffic movement in a blind spot area. Contributing factors are:

A. Failure of block occupancy lights to illuminate with aircraft passage.

B. Failure of block occupancy lights to go out after aircraft leaves the instrumented area.

C. False indications on the display due to intrusions by ground vehicles.

2. The system provides little useful information to the controller. Contributing factors are:

A. The display only indicates that something is traversing the instrumented area. It provides no information as to type of vehicle - ground or aircraft.

B. The attention required to follow traffic movement on the display diverts attention from the main flow of ground traffic under visual observation to a disproportionate extent.

C. Intruders create false and confusing indications on the display which lead to a lack of confidence in the display system.

3. The physical characteristics of the display are satisfactory.

4. Successful operation of a display system such as this, requires that intruders be prohibited and the ability to differentiate betweeen ground vehicles and aircraft be provided.

APPENDIX A

THIS APPENDIX ILLUSTRATES THE RELIABILITY DATA COLLECTION FORM USED IN THE JFK TOWER

DATE	TIME	TYPE ACFT	DIR of TVL	BLOCKS EFF	HOW EFF	PROB CAUSE	CORR ACTION	REMARKS	CONT INIT

If AC operation is normal through system, complete only date, time type A/C and initials

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APPENDIX B

COMPILATION OF CONTROLLER RESPONSES

This appendix contains a compilation of responses to a questionnaire designed to determine the utility of the interim loop display system and to solicity ideas for improvement.

1. Was direction of travel easily determined?

Yes - 13 No - 1

2. Was the displayed information adequate for use in making a control decision?

Yes - 2 No 10

Comments: "Display must be constantly watched to be suitable for making control decisions." "Constant watching of this display results in neglect of other traffic."

3. Was the display of value to you

(a) During restricted visibility?

Yes 1 No 5 Don't Know 5

(b) When portions of the instrumented area were visible?

Yes 3 No 5 Don't Know 5

Comments: "With so many false indications, restricted visibility conditions would be the worst time to use it."

4. What is your opinion of the intelligence obtained from the loop display system as compared with

(a) ASDE?

Better 0 Same 1 Less Effective 12 Complements 2

(b) Visual Observation?

Better 1 Same 1 Less Effective 13 Complements 0

Comments: "Too many lights to observe." "System isn't trustworthy." "I could get the same information by asking an aircraft to report when clear of the area."

5. Did any peculiar weather conditions affect the display?

Yes 3 No 11 No Peculiar Weather 2

Comments: "Heavy rain caused lights to flash as if test button was on." "Heavy rain caused lights to remain on."

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6. Did you encounter any problems with intruders in the system?

Yes 15 No 0

Comments: "Constantly" "That is one of the biggest problems." "Almost continuously."

7. Were you able to determine the approximate speed of the aircraft/vehicle by the progressive illumination of the readouts?

Yes 1 No 13 Not Sure 1

Comments: "Display must be monitored diligently in order to determine relative speeds."

8. Did you encounter periods when the display presentation was confusing?

Yes 12 No 3

Comments: "Several times it appeared to show aircraft nose-to-nose when that condition really did not exist and no intruders were present." "Two or more lights were on as one aircraft passed the area." "Whenever three or more went through the system in proximity, six blocks would light and then two in the middle would go out. Sometimes you thought there was two instead of three."

9. Was any difficulty encountered in retaining identity of an aircraft on the display unit by correlating the aircrafts' position with the observed block illumination after the aircraft was visually observed entering the instrumented area?

Yes 5 No 9

Comments: "That is the only way it could be used." "No difficulty in this small area but I think more difficulty would be encountered over a large area such as the whole airport." "In most cases we could see at least the tail of the airplane."

10. Express your opinion of the usefulness of the display and suggestions for improvement.

"The only usefulness I can possibly see for the display is when aircraft exit runways they could activate lights, therefore assuring the controller they are indeed clear (of the runway)."

"I believe if it was possible to have a display such as the ASDE and the targets simulated on the display, which would show a map of the airport including runways and taxiways, it would be a lot easier for the controller instead of watching lights."

"At the present, the display has little usefulness--too many intruders."

"When the equipment was working, I personally did not use it at all, because I did not think the equipment was accurate enough to base control upon."

"The display does not give enough pertinent information as in regards to the type of aircraft or identifying markings. In working large volumes of traffic, this additional information is needed to effectively control traffic."

"This system must be perfected so that a ground vehicle will not activate the display; until that time I have no confidence."

"The system, in its present state, could not be used for control purposes-- too erratic."

"The information provided by the display does not warrant the necessity of taking one's eyes off the traffic flow on the perimeter in order to view the display."

"All this equipment shows is that something is in that area. You still have to find out if it is a plane, car, or truck. I can get the same information by asking an aircraft I think is in the area if he is."